PB84-245430

Pathogen Reduction Studies in EPA's (Environmental Protection Agency's) Sludge Management Program

(U.S.) Municipal Environmental Research Lab.
Cincinnati, OH

Aug 84

U.S. Department of Commerce
National Technical Information Service
NTIS

PB84-245430

EPA-600/D-84-220
August 1984

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by

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U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-600/D-84-220		PB84 245430

4. TITLE AND SUBTITLE	5. REPORT DATE
Pathogen Reduction Studies in EPA's Sludge Management Program	August 1984
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Joseph B. Farrell	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Wastewater Research Division Municipal Environmental Research Laboratory, CIN-OH Office of Research & Development, USEPA Cincinnati, OH 45268	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
See Item 9	14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Since about 1976, EPA's Sludge Management Program has devoted a substantial portion of its resources towards evaluating existing and new sludge stabilization processes for their ability to reduce or eliminate pathogens. This presentation reviews the nature and extent of these efforts and the plans for future work.

Early efforts concentrated on processes that produce a disinfected sludge, such as thermophilic aerobic and anaerobic digestion and composting. Chemical treatment processes such as liming to pH 12 proved to be less effective than thermal processes because they did not eliminate the eggs of certain intestinal worms (e.g., Ascaris, Toxacara) which were found to be ubiquitous in sludges. Criteria for limiting potential adverse effects from pathogens in sludge applied to land, published in September 1979 (see 40 CFR, Part 257), recognized the different capabilities of processes for reducing pathogens; process conditions to produce the desired reductions were drawn from the above work and are published in the criteria. Future work will include support for further development of EPA's regulations and guidance related to sludge management, to upgrading in a cost-effective fashion processes that reduce or eliminate pathogens in sludge, and investigation of low technology means to disinfect sludge.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release to Public	Unclassified	12
	20. SECURITY CLASS *(This page)*	22. PRICE

EPA Form 2220-1 (9-73)

PATHOGEN REDUCTION STUDIES IN EPA'S SLUDGE MANAGEMENT PROGRAM

INTRODUCTION

The management of municipal wastewater sludge has been an important concern of the U.S. EPA since its inception. Because it is an agency for environmental protection, it is obvious that the EPA should be concerned that sludge be processed in such a way that deleterious environmental and health effects are minimized. EPA also administers a large construction grant program, so it is also extremely interested in seeing that the technology relating to sludge processing, disposal, or use performs well and is cost-effective.

EPA's sludge management program (SMP) is conducted by the Ultimate Disposal Section of the Wastewater Research Division of EPA's Municipal Environmental Research Laboratory at the A. W. Breidenbach Environmental Research Center (AWBERC) in Cincinnati. The primary effort of the SMP has been directed towards EPA's two principal concerns for sludge; it attempts to encourage use of technology for processing, disposing, and using sludge that is cost-effective and at the same time causes minimal harm to the environment and human health. Since about 1977, when attention began to be directed towards regulating the disposal of sludge, the SMP has devoted a substantial share of its resources towards evaluating all aspects of sludge handling for their effects on pathogens and developing new approaches for reducing or eliminating pathogens and their potentially harmful effects. Research on the health effects produced by pathogens in sludge is conducted by a branch of EPA's Health Effects Research Laboratory of AWBERC.

A brief summary of the activities of the SMP from about 1976 to the present is given below:

- Established a technological and scientific base for lime stabilization of sludge
- Showed advantages of thermophilic digestion over mesophilic digestion for pathogen destruction
- Studied infection rate of swine when penned on land on which sludge containing Ascaris suum (a helminth parasite of swine) was applied
- Initiated survey of sludges in U.S. POTW's (public owned treatment works) for parasites
- Cooperated with Sandia Labs in development of gamma ray irradiation of sludge to reduce pathogens
- Demonstrated autothermal thermophilic aerobic digestion
- Demonstrated dual digestion
- Investigated pathogen-reducing potential of short- and long-term lagooning

Until September 13, 1979, when criteria mandated by the Resource, Conservation, and Recovery Act (RCRA) relating to pathogens in sludge were published (1), the nature of our research was guided by the notion that we had better have methods available to disinfect sludge, just in case regulations required it. The criteria published were less restrictive than

anticipated, allowing under certain conditions disposal of partially disinfected sludge. As a consequence, it became important to develop more information on processes that produce partial disinfection.

The criteria established three categories for sludge disposal:

(1) If sludge is not treated by a process that reduces pathogens and vector attraction, it cannot be disposed to the land surface (shallow injection of raw sludge does not qualify because some sludge leaks to the surface).

(2) If sludge is treated by a stabilization process that reduces pathogens to the same degree or better than properly conducted anaerobic digestion, it may be used on the land surface if access is restricted and other restrictions as to crop type are followed. Processes that qualify are called "processes that significantly reduce pathogens" (PSRP).

(3) If sludge is treated by a stabilization process that produces a pathogen reduction equivalent to pasteurization, there are no restrictions to its use insofar as pathogens are concerned. Processes that qualify are called "processes that further reduce pathogens" (PFRP).

Although the criteria created research needs, they provided focus that allowed us to limit some of our efforts. For example, we knew that lime stabilization reduced bacteria and viruses better than anaerobic digestion but, like digestion, had little effect on helminth ova. It qualified as a PSRP and would not qualify as a PFRP. Consequently there was no point for further research.

Our effort since the criteria were published has been about equally divided between filling the information gaps related to PSRP's, and developing low cost PFRP's.

CURRENT RESEARCH ON PSRP

Aerobic Digestion

When the sludge criteria were being written, our group was asked to recommend conditions at which aerobic digestion would reduce pathogens to the same degree as anaerobic digestion. Virtually no data were available on this process, and our work on sludge storage effects (2) indicated that at cool temperatures, aerobic digestion would be ineffective. Consequently we recommended extremely conservative digestion periods (40 days at 20 ^{o}C, 60 days at 15 ^{o}C). Shortly thereafter, we funded work at the University of Florida to get some quantitative data. Table 1 shows an excerpt from this work (3) which indicates very low reductions in bacteria at low temperatures. Full-scale digesters were even less effective than indicated by the bench-scale work. This verified what we suspected. We can be fairly certain that under wintertime conditions, there are hundreds of small plants scattered around the United States using this process and disposing the treated sludge in violation of RCRA criteria.

Our past work indicates that if heat is conserved, sludge is thickened adequately, and mixing is efficient, oxidative processes will heat the digester to as high as 55 ^{o}C. This will pasteurize the sludge. This approach is feasible for a new installation. Existing installations can be

upgraded by partial steps that get the sludge temperatures up to ca. 35 °C. In this case, a 15-day residence time will give performance as good as anaerobic digestion and very satisfactory digestion. A schematic diagram showing suggested modifications is shown in Figure 1. A cooperative agreement to demonstrate this kind of upgrading is in the negotiation stages.

Extended Aeration

Many small extended aeration and brush aeration plants are in use in the United States. Typically they have no primary sludge and their waste sludge has a sludge age of 20-30 days. As the criteria now state, these sludges must undergo a PSRP equivalent to anaerobic digestion if they go on the land. The objection is made that these sludges are already well stabilized and are already reduced in pathogens.

We have been engaged in research that, in its preliminary stages, shows that these sludges have lower pathogen levels than a raw sludge from a conventional plant but not as low as would be obtained if the conventional raw sludge were anaerobically digested. So apparently an intermediate treatment of some kind (e.g., sludge drying beds, short-term lagoon storage) is needed to make these sludges qualify for use on land.

CURRENT RESEARCH ON PFRP

Long-Term Storage

In the late 1970's, we became interested in the potential of storage of sludge in lagoons as a method for eliminating pathogens. Some of the data we obtained (2) are shown in Table 2. The data show excellent reductions in bacteria and viruses if temperature is above 20 °C. At this time we became aware of the presence of helminth eggs in virtually all sludges and of their resistance to adverse environments. Our qualitative tests showed substantial survival of Ascaris after 6 months in sludge which temporarily dashed our hopes that long term storage would essentially disinfect sludge.

The qualitative nature of all available information on survival of helminth eggs motivated us to sponsor a project with Dr. Edna Kaneshiro at the University of Cincinnati to quantify the reductions in helminth egg densities with time. The project is complete and the final report is in review. In these investigations, huge initial densities (10,000/100 ml) were used so that reductions of several logs could be observed. As Figure 2 shows, storage at 25 °C reduced the numbers of Ascaris eggs recovered and the fraction viable to extremely low levels. This encouraged us to believe that long term storage could be an PFRP if the conditions were right. We have high hopes that we have stumbled on a PFRP for some of our warmer states, and, even more importantly, a pathogen-eliminating procedure for third-world countries in the tropics where parasite infestations are pandemic. We currently have a demonstration underway, being conducted by Tulane University, in which the survival of helminth eggs in simulated sludge lagoons in Port Aransas near Corpus Christi and New Orleans are being followed. Definitive results from this project are not expected before June 1985.

Dual Digestion

Both anaerobic and aerobic digestion can be conducted at temperatures in the vicinity of 55 °C. If short-circuiting does not occur, these are PFRP's. However, there are problems with both approaches. Anaerobic digestion is claimed to be unstable above 50 °C and 50 °C is just not hot enough to assure destruction of helminth eggs. Aerobic digestion (using diffused air) might require more attention to keep a reactor above 55 °C than most POTW operators care to give to a process. European investigators have developed an anaerobic digestion process that at least avoids potential process instability. The sludge is pasteurized first at 70 °C and then is digested at mesophilic temperatures. After a period of time, pathogens originally in the mesophilic digester are washed out or destroyed. This same effect is achieved by dual digestion (see Figure 3). In this process, sludge is aerobically digested with oxygen. After one day's residence time, the sludge reaches 55 °C. The sludge then passes to an anaerobic digester where digestion proceeds at some equilibrium temperature between 40-50 °C. The process is reportedly very stable despite the fact that digestion occurs outside of the normal mesophilic (35 ± 2 °C) and thermophilic (50 ± 2 °C) digestion ranges. We funded a demonstration at Hagerstown, Maryland, that demonstrated feasibility. Plants have been erected in Henderson, N.C., and Lackawanna, N.Y. An evaluation is planned in the near future to determine whether the process can operate stably for a sufficient time to produce a pathogen-free sludge.

Regrowth After Composting

A serious concern with any PFRP is the potential for regrowth of pathogenic bacteria in the finished product. Certain processes such as heat treatment or pasteurization leave the sludge devoid of or greatly reduced in vegetative bacteria. Contamination downstream can result in explosive growth. This situation has occurred in Europe where pasteurization after digestion was once a choice disinfection method. As noted above, pasteurization before disinfection is now favored. We have been concerned about contamination with pathogenic bacteria with subsequent growth in sludge compost and have a project underway with Dr. Wylie Burge of the USDA in Beltsville. His tentative findings to date indicate that (1) it is not practical to try to produce a product so thoroughly composted that it will not support some regrowth of *Salmonella*, and (2) excessive temperatures at the termination of composting (e.g., 70 °C) reduce vegetative microbial forms to low densities and increase the potential for growth of contaminating bacteria. In composting, it may be desirable to reach disinfection temperatures early in the process and complete the composting at lower temperatures. This will leave competitive organisms present in the compost that will resist any regrowth from pathogens that might have survived the composting or might have contaminated the product.

PLANS AND NEEDS FOR THE FUTURE

Projects for the future are not very grandiose, because our resources are slim. We will include evaluation of a variety of relatively simple add-on processes that can be used to increase pathogen reductions from processes that do not meet the PSRP requirement. Studies will also be conducted on understanding the parameters that control the pathogen-reducing ability of various PSRP's such as anaerobic digestion so that process adjustments can be made to upgrade pathogen-reducing ability.

EPA is now making a determined effort to complete its task of regulating sludge processing and the quality of sludge products. A substantial part of

our work will be to cooperate with regulatory staff by providing information and assessing regulatory approaches.

Another anticipated task will be evaluating the PSRP's and PFRP's proposed by others.

One very evident need that, if filled, would have a great impact on sludge processing to reduce pathogens, is for a cost-effective low-technology method for eliminating helminth eggs in sludge. Present methods are either more expensive than desired or the technology is too involved, particularly for small POTW's. Even if such a process only reduced the helminth eggs, it would have substantial impact. Such a process could become a PFRP by putting it in tandem with digestion and short-term lagooning. If sludge had no helminth eggs, the required waiting periods before crops for direct human consumption could be grown could be reduced.

The development of processing techniques and investigation of the pathogens in sludge is far from complete. For example, we do not have techniques for monitoring some pathogenic bacteria and viruses of concern, and no doubt improved pathogen-reducing techniques can and will be developed.

A concern that we have in the SMP is that we have our eyes a little too much on target. The existence of a regulation makes research planning almost too easy; creative approaches that possibly could lead to a different but more efficient regulation tend to be overlooked.

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TABLE 1

BACTERIAL SURVIVAL DURING BENCH-SCALE AEROBIC DIGESTION

WITH 15 DAY DETENTION TIME

	LOG REDUCTIONS	
	28 °C	6 °C
S. TYPHIMURIUM	1.24	0.23
S. FAECALIS	0.92	0.10
E. COLI	1.13	0.23
P. AERUGINOSA	0.28	0.29
TOTAL AEROBIC BACTERIA	0.34	0.07

1. ADAPTED FROM TABLE 1 IN FARRAH, S. R., AND BITTON, G., APPL. & ENVIR. MICROBIOLOGY, 45, 174-181 (1983).

TABLE 2

DIE-OFF OF BACTERIA IN STORED DIGESTED SLUDGE

ORGANISMS	LOG OF ORGANISM DENSITY (NO./100 ML)					
	STORAGE TIME (WKS)					
	0	2	4	8	16	24
FECAL STREPTOCOCCUS						
4 °C	6.5	6.4	6.4	6.2	6.1	6.7
20 °C	6.5	5.3	5.0	4.4	BDL[1]	BDL[1]
FECAL COLIFORM						
4 °C	7.9	6.9	6.1	5.5	5.2	3.0
20 °C	7.9	5.1	4.7	3.7	3.8	BDL[1]
TOTAL COLIFORM						
4 °C	8.4	--	7.7	7.5	6.6	3.0
20 °C	8.4	5.7	5.3	4.5	3.8	BDL[1]
SALMONELLA						
4 °C	2.4	2.7	2.4	2.4	2.1	BDL[2]
20 °C	2.4	0.96	0.56	BDL[2]	BDL[2]	BDL[2]

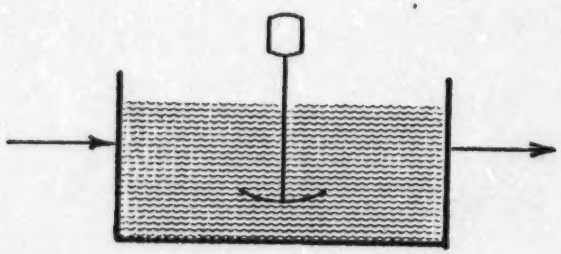
(1) BDL - LESS THAN 1000/100 ML FOR INDICATOR ORGANISMS

(2) BDL - LESS THAN 3/100 ML FOR SALMONELLA

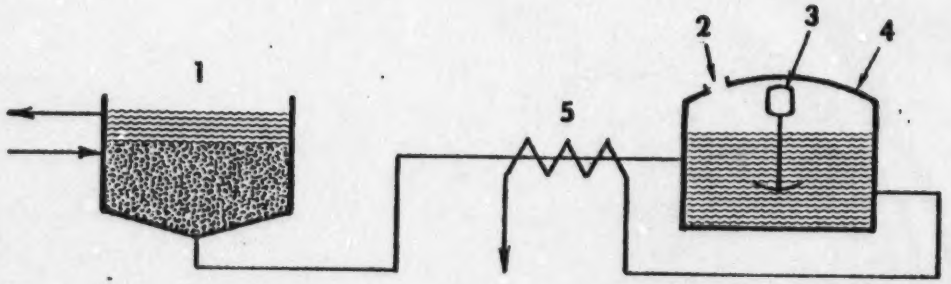
FIGURE 1

MODIFICATION OF AEROBIC DIGESTER TO RETAIN HEAT

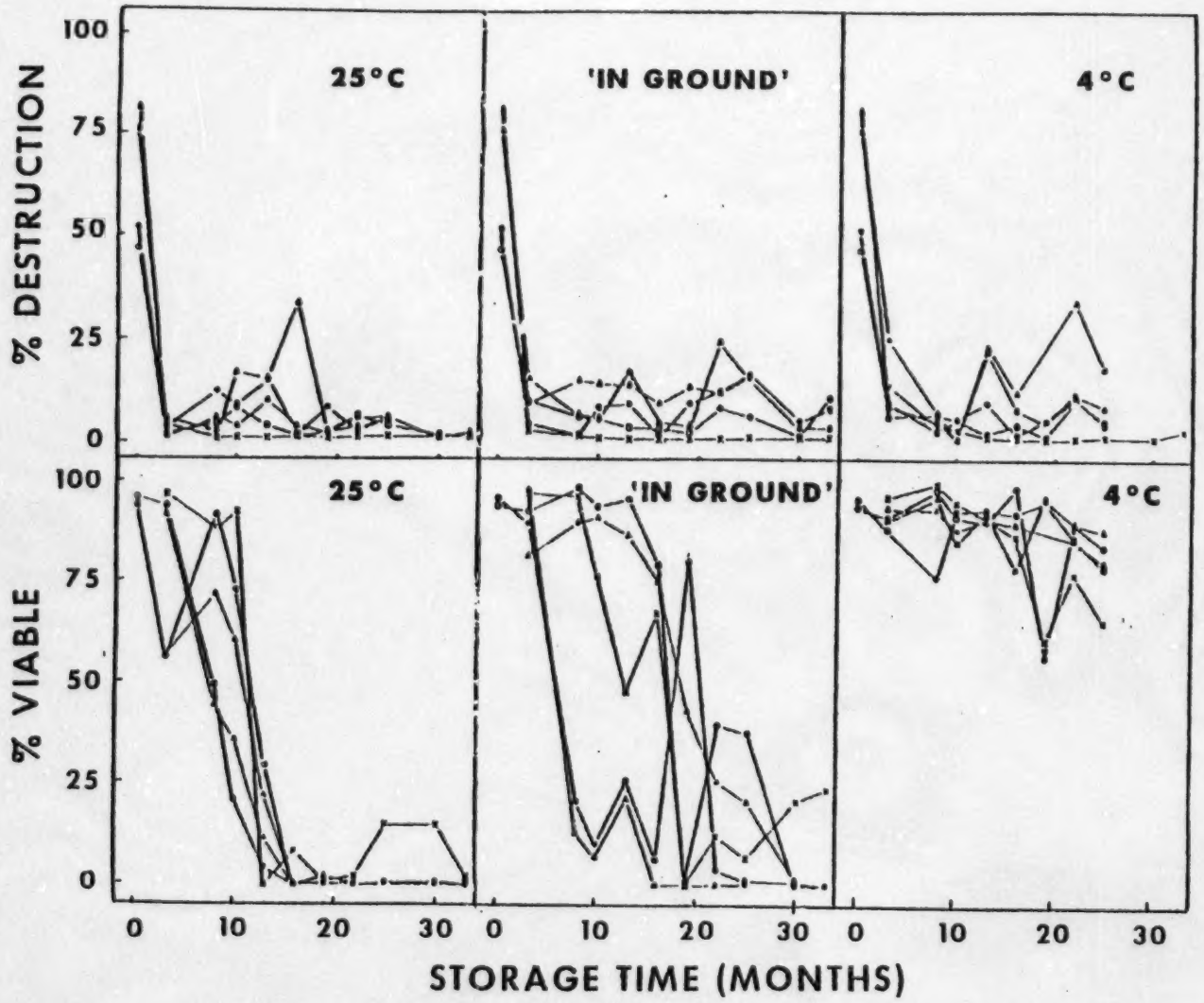
CONVENTIONAL



MODIFIED



1. THICKENER
2. VENT FOR AIR EXCHANGE
3. HIGH EFFICIENCY AERATOR-MIXER
4. COVERED AND INSULATED DIGESTER
5. HEAT EXCHANGER



DESTRUCTION AND VIABILITY OF ASCARIS EGGS IN STORED DIGESTED SLUDGE

FIGURE 2

FIGURE 3

DUAL DIGESTION SYSTEM AT HAGERSTOWN